MICRO-ORGANISMS AND SULPHIDE IN A POLLUTED ESTUARY

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ABSTRACT

Some of the major roles of micro-organisms in estuarine environments are described and, by considering the ways micro-organisms transform sulphur and its compounds, it is shown that microbial activities are influenced not only by what goes on in an estuary but also by events in its catchment area.

One of the most important activities of bacteria in an estuary is the decomposition of organic residues. The bacteria involved obtain their energy and organic nutrients from the residues of dead shellfish, fish, worms, birds, seaweeds and so on. In well aerated or aerobic situations the bulk of such organic matter is oxidized by bacterial action to form inorganic substances like carbon dioxide, ammonium and phosphate. Such inorganic substances are released in a form that can be used by plants and by bringing plant nutrients back into circulation again, the decay bacteria help to maintain the fertility of an estuary. When, however, an estuary is enriched by a surplus of nutrients which favours the growth of an overabundance of plants it becomes eutrophic.

An estuary favours bacterial growth because it is fertile, there is always a large quantity of decomposable material present or flowing in from rivers and drains, the mud flats remain moist at low tide, and the temperature regime is relatively stable. During organic matter decomposition the demand for oxygen is high and within moist mud or a mass of dead seaweed the physical environment is such that the oxygen supply generally cannot meet the demand. Oxygen is not very soluble in water and its rate of diffusion through water is almost negligible compared to its rate of diffusion through air. So when the demand for oxygen cannot be met, aerobic bacteria no longer function, and anaerobic bacteria resort to other oxidizing materials. Nitrate, for example, can be used in place of oxygen. When the supply of nitrate is exhausted, most bacteria become inactive, but there are some that are able to use sulphate as a source of oxidizing power. Sulphate is reduced by such bacteria, to sulphur or even further to hydrogen sulphide. Hydrogen sulphide is a corrosive gas that smells of bad eggs, is toxic to most forms of life, and is very soluble in water. This unpleasant substance, besides being an ingredient of the schoolboy's stinkbomb, is associated with decay under conditions of reduced oxygen supply. Thus, when seaweeds like sea lettuce decompose on the mud flats, sulphide formed by anaerobic bacteria causes an unpleasant smell.

Sulphide lost by volatilization from an estuary to the atmosphere is rapidly oxidized by photochemical reactions to sulphur dioxide. Much of the sulphur dioxide becomes dissolved in rain water and if the rain falls on to land most of the dissolved sulphate would eventually find its way back to estuaries.

Sulphide can be acted upon by certain bacteria which abound in the mud of shallow estuaries. These bacteria are photosynthetic and like plants they use sunlight as their source of energy and build up organic compounds using carbon dioxide as their source of carbon. Unlike plants, however, they are intolerant of oxygen and are confined to oxygen-deficient habitats. Many of them also have a bizarre requirement during photosynthesis for sulphide as a reducing agent to convert carbon dioxide to organic substances, and the sulphide is oxidized to sulphate.

An estuary environment favours photosynthetic bacteria because the surface mud is moist, lacks oxygen, is exposed to sunlight, and during warm weather there is a plentiful supply of sulphide from which the bacteria can form sulphate. These bacteria grow abundantly in an estuary and produce organic matter which, when they die, is broken down by decay bacteria, a process which enriches the habitat with nutrients.

There are other bacteria besides the photosynthetic bacteria that oxidize sulphide. The thiobacilli obtain their energy not from sunlight or preformed organic food, but from oxidizing sulphide in the presence of oxygen to sulphate. Such organisms are common in estuaries, but only where oxygen is freely available.

To summarize so far we have a biological cycle of sulphur in the estuary. Sulphur comes in mainly as sulphate dissolved in rain, sea, river or drain waters or in sea spray. Once it is in the estuary, it is reduced to sulphide by anaerobic decay bacteria living in oxygen-deficient muds or organic debris. Such sulphide is in turn oxidized to sulphate by photosynthetic bacteria or thiobacilli. The speculation I wish to put forward is that a polluted estuary is a special microbiological situation, where sulphur tends to accumulate because of the recycling described above between the anaerobic sulphate-reducing and the sulphate-oxidizing bacteria.

There are some issues that could be of wide significance in environmental pollution and eutrophication. Both sulphate-reducing and photosynthetic bacteria can fix gaseous nitrogen and convert it into organic nitrogen compounds, and as both groups of bacteria are active in an estuary, they could bring about nitrogen accumulation and contribute to eutrophication.

The decay bacteria cause the environment to become reduced and one consequence of this is the conversion of insoluble inorganic phosphates into water-soluble forms. Phosphates in general have very low solubilities in water but under reducing conditions many phosphates, such as those present in minerals and muds become more soluble, as much as two- or three-fold. As plant growth in aquatic ecosystems can often be increased by favourable concentrations of nitrogen and phosphorus, it would seem that the biological transformations of sulphur would enrich the estuary and the increased supplies of nutrients would lead to eutrophication.

If the supply of sulphur to a polluted estuary and all water courses draining into it was reduced, we could expect conditions to improve. Less plant material and other organic matter would be formed and there would be less decay. Consequently less sulphide would be formed and accumulated. A decrease in the amount of this toxin would occur enabling recolonization by the original flora and fauna of this river.

There are several natural sources of sulphur supply to an estuary, but these are difficult to regulate, e.g., sea spray. The sources that come under human influence are various and include sulphur compounds in industrial wastes, effluent from sewage oxidation ponds, and in eroded soil materials brought in by rivers and drains especially during times of flood. Fertilizer containing sulphur or sulphate is another source. After application to the land sulphur becomes oxidized by soil thiobacilli to sulphate, and subsequently much of the sulphate is washed or leached out of the soil into drainage waters. A major contribution comes from superphosphate which besides containing 9% phosphorus also contains 12% sulphur as gypsum (calcium sulphate). Although the phosphates in fertilizers have been blamed for freshwater eutrophication, it seems improbable that they cause such pollution because phosphates are almost insoluble in water and hence immobile in soil. Sulphate on the other hand is very mobile and once it reaches an aquatic system its biological reduction to sulphide in the anaerobic bottom mud might well contribute to increased phosphate solubility. The obvious method of control would be to use phosphate fertilizer with a low sulphur content, but I have not seen the mechanism of eutrophication suggested here or its control mentioned in the literature.

Sulphur is also derived from sulphur-containing fossil fuels burnt in urban areas. Sulphur dioxide released to the air when such fuel is burnt is rapidly converted to sulphate and deposited on land, trees and buildings by rain and smog. Ultimately much of this sulphate is washed down into the soil and finds its way into drains, sewers and streams leading to an estuary. It is logical that a reduction in the use of sulphur-rich fuels in urban areas close to estuaries would alleviate the sulphur loading on the estuary. Thus even when we consider an ecological system as complex as an estuary we cannot think about it in isolation, but need to take account of the influence of outside factors such as the few examples given here.